Engineering Residual Stress to Prevent Failure of Systems

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Fatigue failure – cracks grow after many cycles; Aloha Airlines Flight 243 (Honolulu) – serious fatigue

4-28-1988 After 89,090 flight cycles on a 737-200, metal fatigue lets the top go in flight.

Maintenance related fatigue failure along lap joint S-10L, led to explosive decompression

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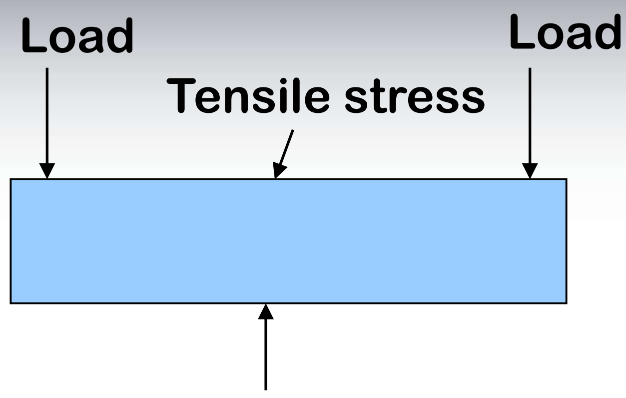
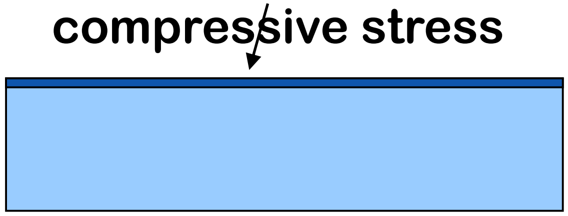
Fatigue cracks initiate and grow in areas that experience tensile stress loading – i.e. things that flex and vibrate



Peening adds protective layer of compressive stress



Ball peen hammer

Shot peening

Laser peening

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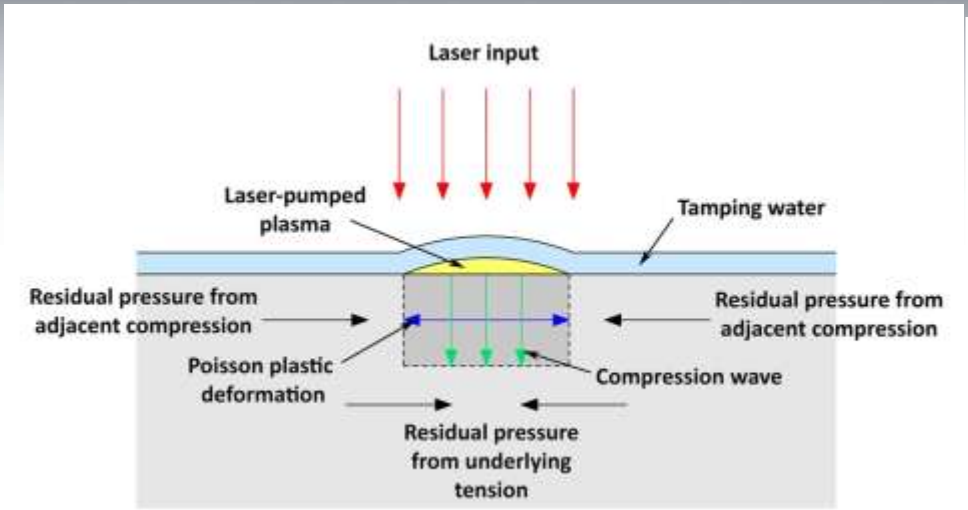
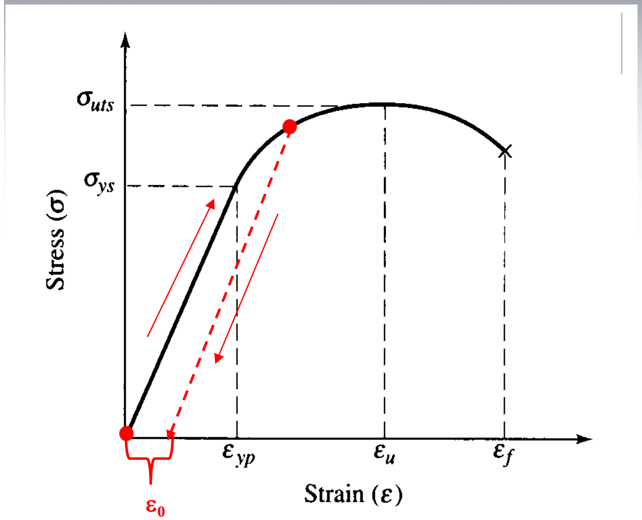
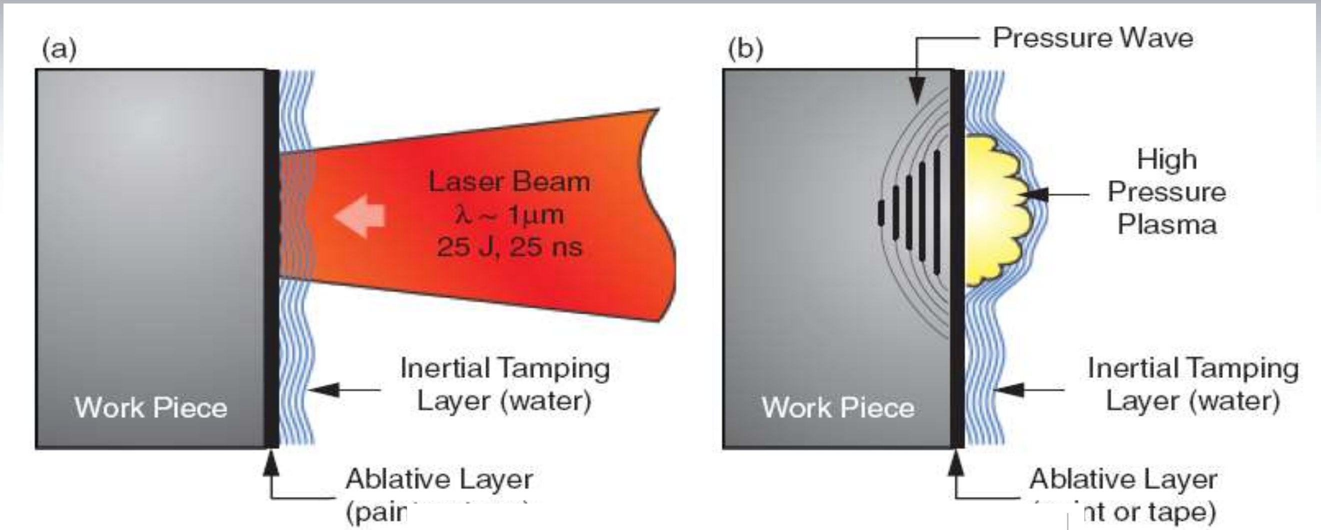
Laser peening generates plastic deformation normal to a surface; transverse strain results in compressive stress

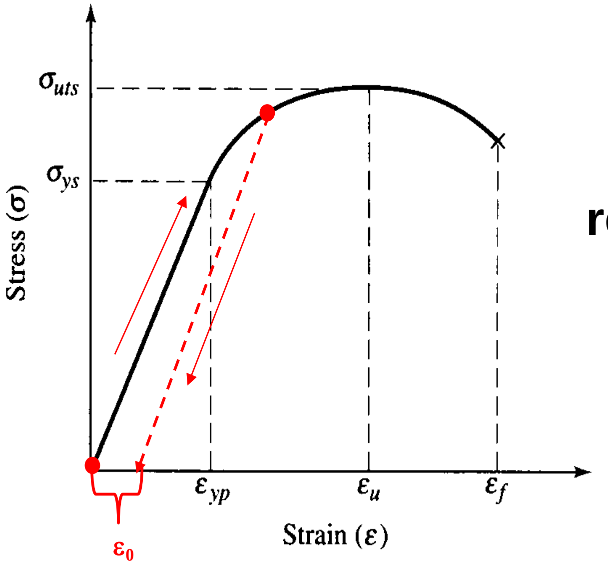




- **Plasma generated shock plastically compresses metal normal to the surface**
- **Metal expands transversely to conserve volume (Poisson ratio)**
- **Surrounding material resists the expansion, setting up a residual compressive field near the surface with an underlying tensile field**
- **The properties of the metal (heat treat state, hardness, cold work, etc.) remain unchanged by the process**

Laser peening plastically deforms near surface initiating residual stress and strain





Stress vs. strain response during LP (idealized)

Nd:glass laser provided the breakthrough in performance and reliability – 1000 MW peak power

Available “up time” readily exceeds 97%; unprecedented for this class of laser system*

*Based on detailed production shutdown reports 1/1-10/31/04

- Laser technology developed at LLNL as part of Laser Program
- Initially funded by DARPA with interest in high peak and average power lasers - 1985
- DARPA funded for X-ray Lithography -1989-92
- Air Force funded for satellite illumination 1992-96
- Curtiss-Wright Corporation funded under CRADA for laser peening 1996-2002
- Tech transferred for industrial laser peening in 2002

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Solving the failure of Titanium engine blades launched Curtiss Wright laser peening in 2002

Laser peening is being applied to eliminate fatigue failure in high value commercial jet engines.

See Austrialian Transportation Safety Board Report 8/01 “Examination of a Failed Blade …. Boeing 777-300, A6-EMM” http://www.atsb.gov.au/aviation/tech-rep/8-01/8-01_Final.pdf)

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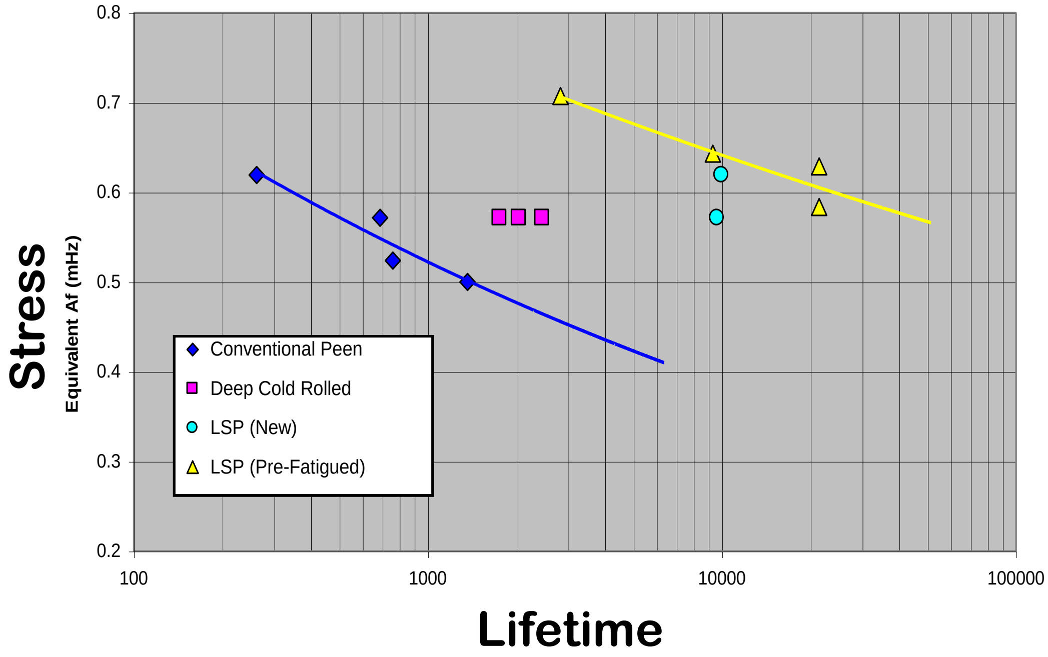
Laser peening extends lifetime of blades by > 20x – saves airlines $Ms annually

Over 40000 blades have been treated for engines powering 777s, 787s, A340s, A350s, G550s, G650…



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We are now laser peening on three continents with fixed and transportable systems

- **Deployments:** **Livermore CA 4/02**

  Earby, UK 5/04

  Fredrickson WA 4/08 - 747-8 panels
  Ogden, UT 10/10 – F-22 structure
  Singapore 1/12 - Blade peening

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Examples of production laser peening


A350 XWB

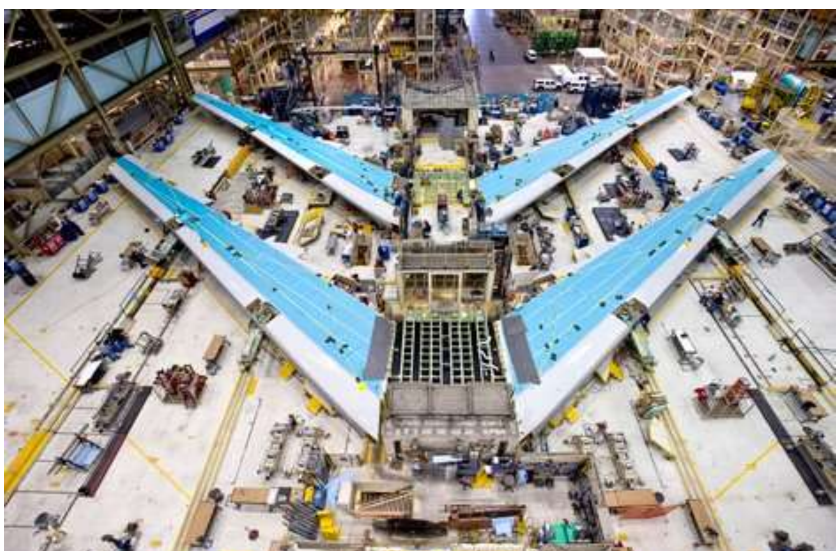

787 Dreamliner


787 Engine Fan


Power generation gas and steam turbines

Laser peening forms thick sections of wing panels for the new 747-8

Peening designed to produce strain for precision shape generation in thick (1”) panel sections



World’s first aircraft with laser formed panels delivered 2011

New Air Force Ones will have laser formed panels

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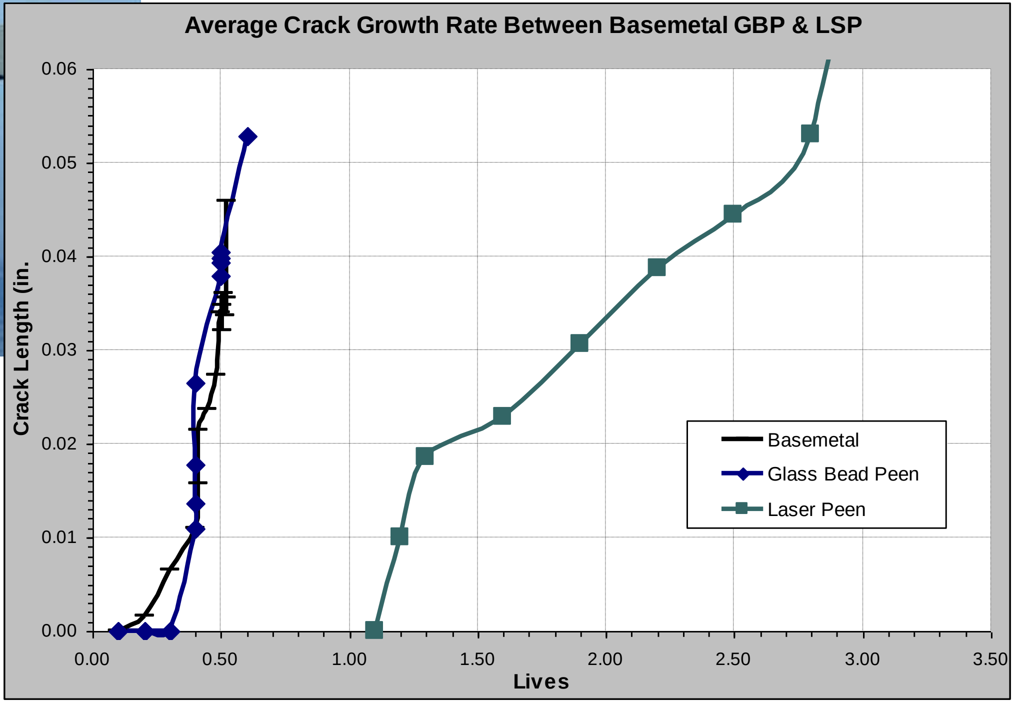
Test results for F-22 structure show delayed crack initiation and slower crack growth with laser peening



Laser peening deployed in Palmdale CA on F-22 aircraft

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Tail hook shanks have fatigue issues at the hook attachment end

T-45 tail hooks statistically require replacement at 400 traps vs. goal of 2000

NAVAIR estimates replacement cost of $63k

T-45 hook shank (shown here)

 Proprietary and Confidential

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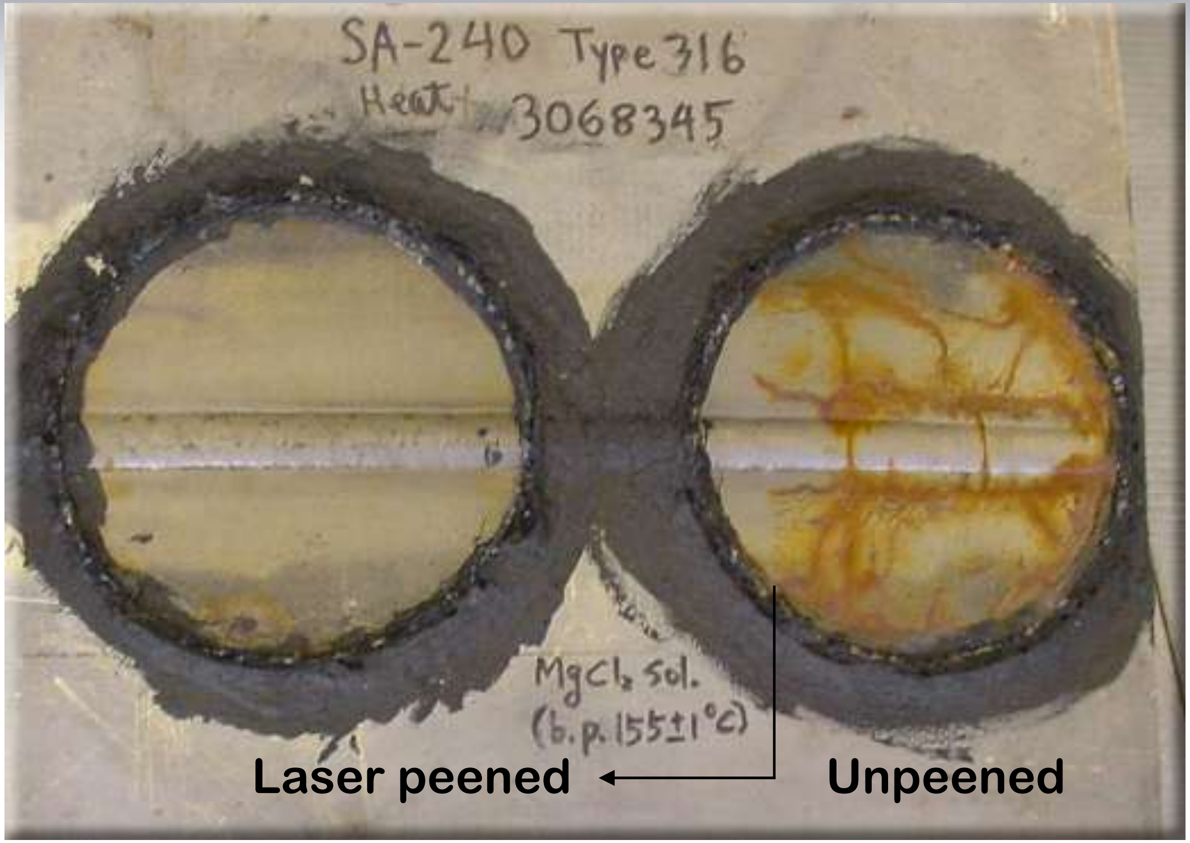
MIC's LP meets performance requirements at affordable cost to extend engine FOD tolerance

MIC Laser Peening processing can meet required performance specs and will save $Ms in unexpected engine replacement costs

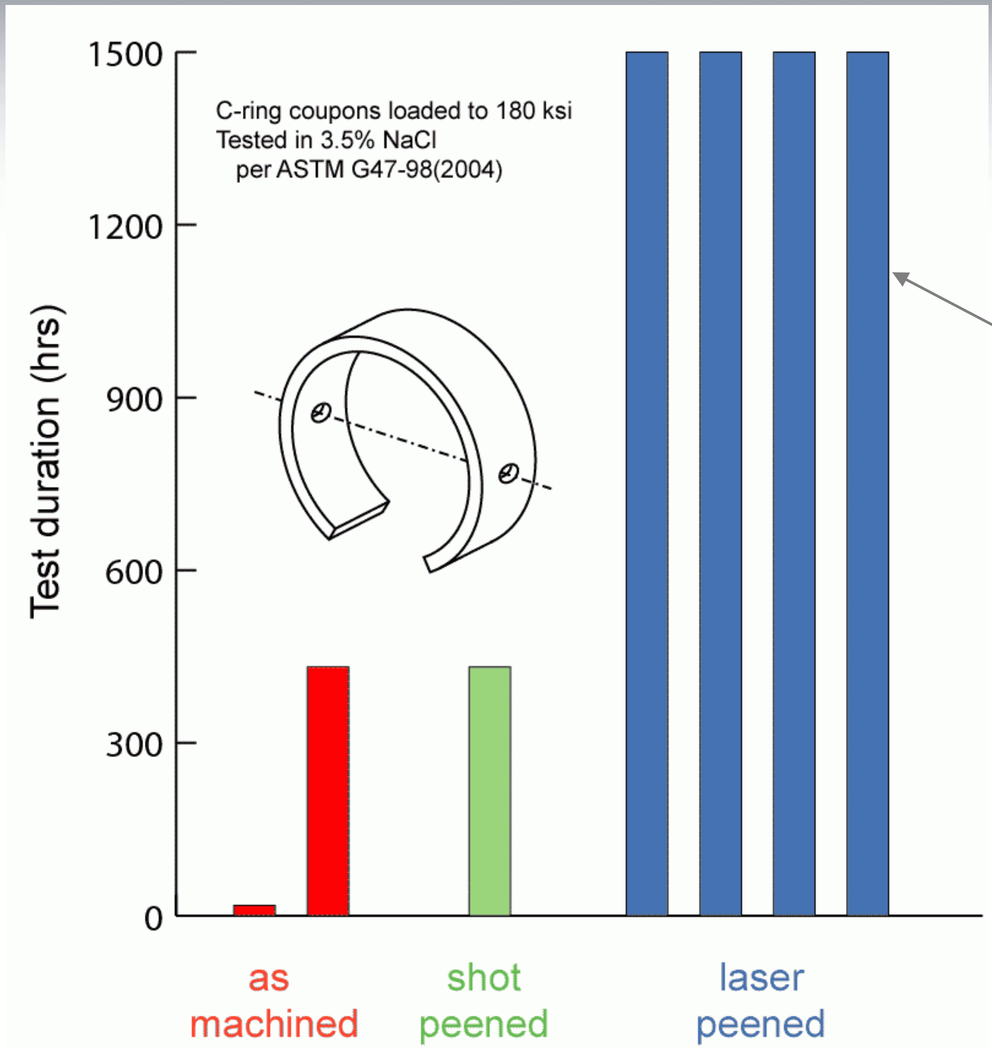
MIC high rate transportable LP systems can be located where needed to achieve time and cost efficient processing

Laser peening of welds prevents SCC and corrosion



Laser peened area is free of stress corrosion cracks and rust, in dramatic contrast to the unpeened area

Laser Peened 300M C-rings did not fail in an alternate-salt-immersion stress corrosion cracking test



Experiment terminated without failures after 2 months

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Summary

- Laser peening is well established as a design, manufacturing & overhaul tool for enhancing fatigue life and fatigue strength of components
- Laser and shock physics technology developed at LLNL was successfully transferred into an industrial process
- We are continuing to develop new applications

Laser peening technology enables higher performance, more efficient and longer lasting systems

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